USE OF REINFORCED EARTH® FOR CONSTRUCTION OF THE SM RAMP ON THE SPRAIN BROOK PARKWAY

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Introduction

The New York State Department of Transportation's first Reinforced Earth® project was completed in 1977. Since then, the use of this material has resulted in substantial savings and good performance on an increasing number of projects.

To date, the Department has used Reinforced Earth in the construction of retaining walls, bridge abutments and associated wingwalls, and to strengthen an existing dam.

One of these projects, a long highway ramp on a compressible foundation, is presented in this case history. Design considerations, construction procedures, and performance observations are discussed.

Overview

The Sprain Brook Parkway project in Elmsford, New York currently ranks as our most extensive use of Reinforced Earth. The project incorporates approximately 118,000 sq ft of retaining walls, abutments and wingwalls. The SM ramp is presented because it typifies the design and construction considerations experienced on the thirteen Reinforced Earth projects in New York State to date.

Geotechnical studies were conducted to determine pile drag on an adjacent existing structure and to predict settlement and stability of this ramp. As the ramp crosses the flood plain of the Saw Mill River it varies in height, reaching a maximum of 51 feet.

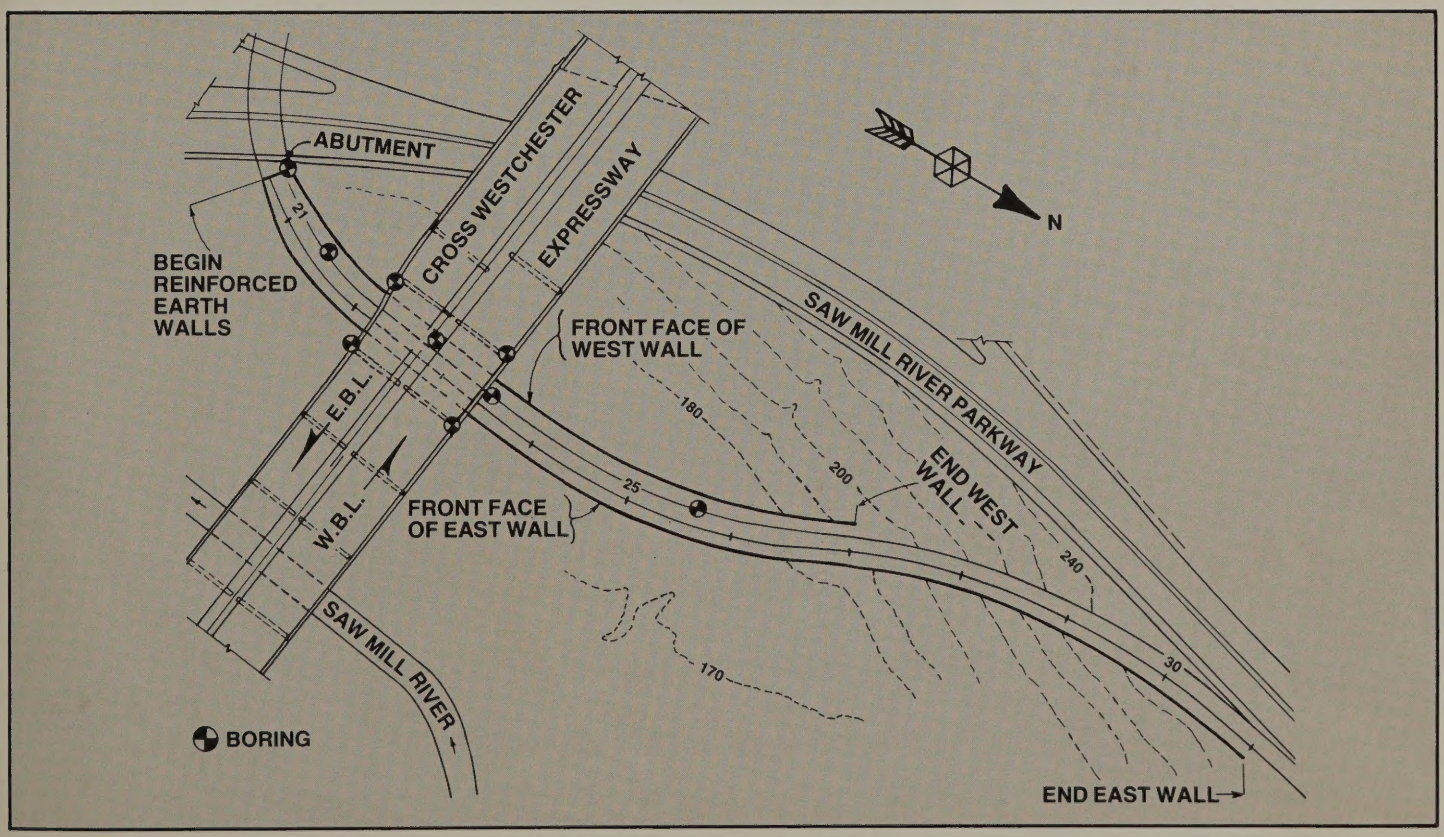

Figure 1. Plan view.

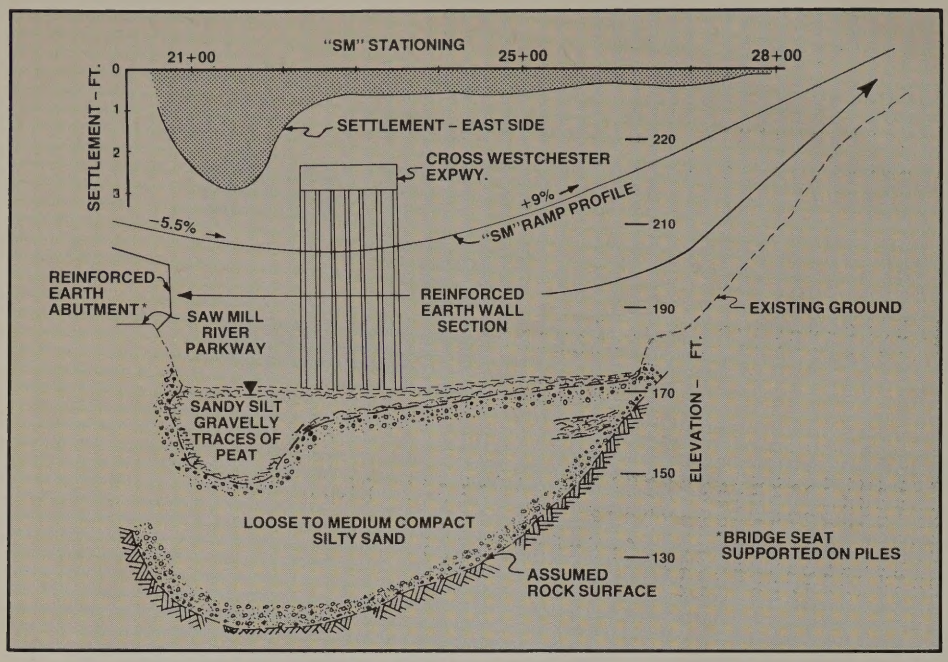

Figure 2. Subsurface conditions and settlement profile.

Design Considerations

The SM ramp connects the Saw Mill River Parkway (northbound) and the Cross Westchester Expressway (eastbound). It follows a curved, horizontal alignment beneath a viaduct of the Cross Westchester Expressway (See Figure 1). The vertical alignment is on steep grades (See Figure 2).

Initial planning considered a simple embankment section for the ramp. However, it was found that the embankment would spill around Piers 4 and 5 of the Cross Westchester viaduct and generate drag forces on existing piles estimated at 70 tons per pile. The existing 30-ft long piles were indicated to be 35-ton capacity cast-in-place concrete. Information on actual lengths of pile driven was not available. The embankment proposal was, therefore, unacceptable unless drag forces could be substantially reduced.

The use of lightweight fill (at 70 lbs/cu ft) was contemplated to reduce drag forces. But even this substitution would result in drag forces on the order of 30 tons per pile. This design approach was not satisfactory. Furthermore, a lightweight embankment fill for the portion under the viaduct would have been very costly.

Two other alternatives were considered: build this ramp as a viaduct structure or, use Reinforced Earth to form a box cross-section about 40 ft wide. The use of vertical walls would move the ramp load further from the piers, decreasing the drag force to an estimated 10 tons per pile (See Figures 3 and 4). Reinforced Earth would only reduce the original assumed pile designed safety factor from 2.0 to 1.7.

Cost analysis indicated that Reinforced Earth, with normal granular backfill material, would be much less expensive than a viaduct structure. The small reduction in pile safety factor at the two existing piers was considered acceptable. As an additional benefit, the Reinforced Earth structures would eliminate the differential settlement between a cast-in-place structure and surrounding fills.

Reinforced Earth was also used for a retaining wall built at the abutment location adjacent to the Saw Mill River Parkway. This Reinforced Earth end structure was built around the supporting piles.

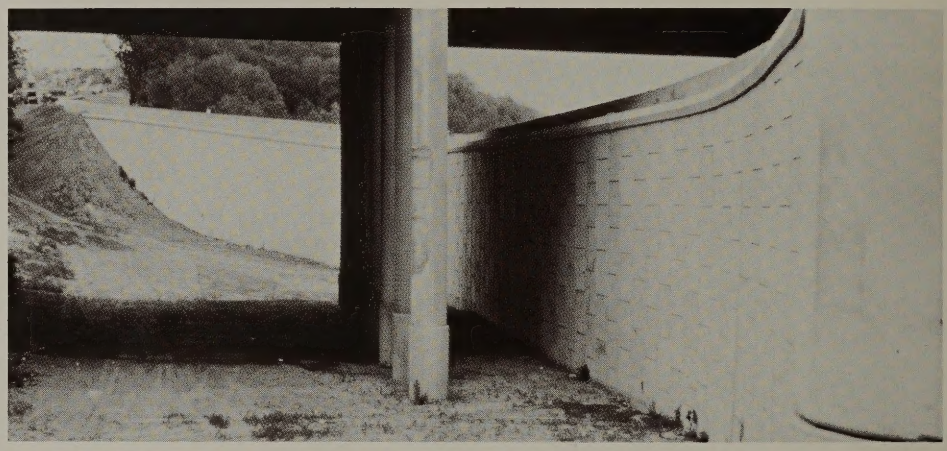

Figure 3. West wall of SM ramp.

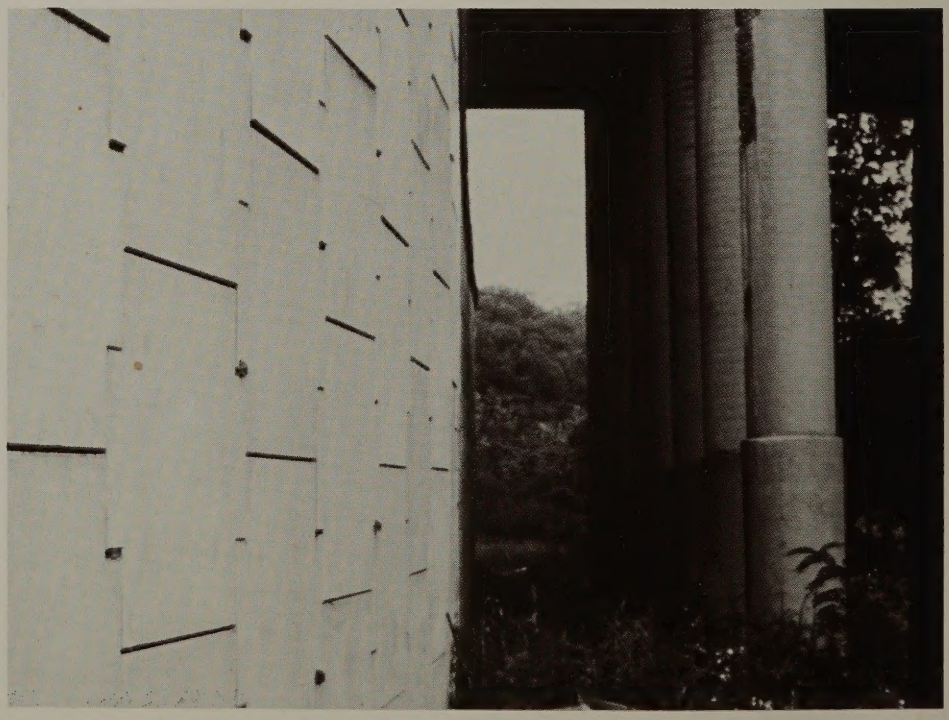

Figure 4. East wall of SM ramp.

Design Analysis

The ramp extending from the abutment would be supported on each side by a Reinforced Earth wall for most of its length. The reinforcing strips for each of the parallel walls would be placed in a staggered pattern to avoid strip interference. The walls would be independent structures, not tied together. This was accomplished as shown in Figure 5.

Figure 2 illustrates the general subsurface profile extending from the north abutment across the Saw Mill River flood plain. The soils are predominantly granular alluvial deposits with varying amounts of organic material near the surface. The percentage of organic material found in the boring samples was low enough to indicate that these deposits would behave as a granular material and consolidate rapidly as the loads were placed.

Settlement

Analyses at the abutment site indicated that steel H-piles, driven to refusal, would be required to prevent settlement at the end of the two-span curved, continuous structure over the Saw Mill River Parkway (See Figure 6). About three inches of settlement was expected at this location due to the embankment load. The piles would be driven before beginning Reinforced Earth construction to avoid striking the reinforcing strips.

Granular backfill was specified to be compacted to 95% Standard Proctor Density for each lift of backfill. Pile drag was to be reduced by having the top 20 ft of pile cleaned and coated with a 0.2-inch thickness of bituminous material (asphalt cement). There was no provision for instrumentation of these piles.

Stability and settlement analyses were necessary because of the compressible soils in the flood plain. It was determined that stability would not be a problem although significant settlements were expected. The maximum computed settlement, based on the boring information, was approximately one foot. There was some concern that undetected compressible deposits in the flood plain could cause greater settlements. Even if so, it was expected that The Reinforced Earth Company's recommended differential settlement guideline of one foot over a distance of 100 ft would not be exceeded.

It was recognized that in order to meet the specified profile requirements of the ramp, the placement of the top course of panels should be delayed until settlement had occurred. The waiting period estimated for this to occur was two weeks. Special topping-off panels would then be cast to the specified height.

Figure 5. Placement of reinforcing strips extending from east and west walls.

Another feature of the Reinforced Earth ramp section across the flood plain on the Saw Mill River side was the specification of filter fabric over the horizontal and vertical joint up to the water level. This would guard against escape of backfill materials through the joints during and after periods of flooding.

Construction and Performance

This ramp was part of a much larger project prepared for contract with a bare minimum of detailed design and plan review. These circumstances were compounded by the fact that the ramp crosses an area of varying foundation soils and follows a sharply curved alignment with steep grades and limited construction access. Inevitably, there were certain plan omissions, such as missing drainage details, that resulted in inconsistencies between the Department's plans and The Reinforced Earth Company's design drawings.

For example, the reinforcing strips of the "cheek" panels at the north abutment were supposed to be clear and independent of the abutment itself. However, the top panels on the west side of this pile-supported abutment were unintentionally anchored into the

Figure 6. Reinforced Earth retaining wall at the north end of the structure above the Saw Mill River Parkway.

Figure 7. Settlement gaps resulting from incorrect attachment of reinforcements to the bridge seat supported on piles.

abutment and, therefore, were restrained from settling as the foundation soils consolidated (See Figure 7). This situation was easily corrected by detaching the panels where necessary and refastening them once settlement was complete.

In another situation, the settlement of the walled ramp section across the flood plain turned out to be much greater than the anticipated one foot. The actual settlement profile, shown on Figure 2, indicated a maximum of 2.9 ft. It is significant that differentials exceeded the recommended settlement guideline by about 100%. However, the walls accommodated the additional settlement without distress (See Figures 8 and 9).

Settlement occurred at a noticeable rate while the walls were under construction. Elevations for adjacent leveling pads at steps had to be adjusted to ensure continuous horizontal joints. This was a nuisance problem because of the many steps called for in the design. The wall curvature, and on-going settlement as panels were being set, required a substantial effort to maintain panel alignment and tolerances during backfilling and compaction.

The plan for determining dimensions of topping-off panels was not implemented because settlement continued beyond the two-week waiting period. A modified top section was accepted to eliminate the need for more panels. The new design used Jersey Barriers just beyond the edge of pavement where guard rails were originally specified. Granular fill material was placed outside the barriers and sloped down to the top of the Reinforced Earth walls. Construction of the modified top sections is shown in Figure 10.

The placement and compaction of backfill around previously-driven piles was accomplished successfully. This procedure has not presented problems on subsequent jobs, and will work well where pile spacings are adequate to accommodate small, mechanical compaction equipment.

Access was extremely limited during construction. The only practical access was from the Saw Mill River Parkway, at the north end of the ramp (See Figure 1). The narrowness of the ramp section required trucks delivering materials to back down the ramp alignment and drive out after unloading (See Figures 11 and 12).

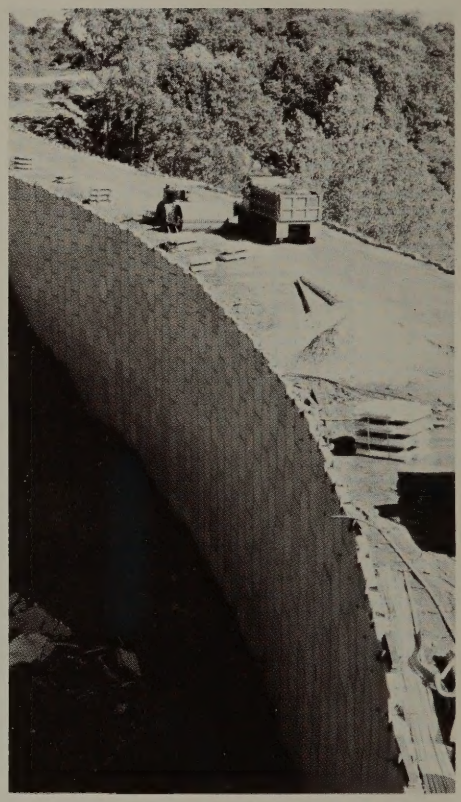

Figure 8. View of west wall looking north.

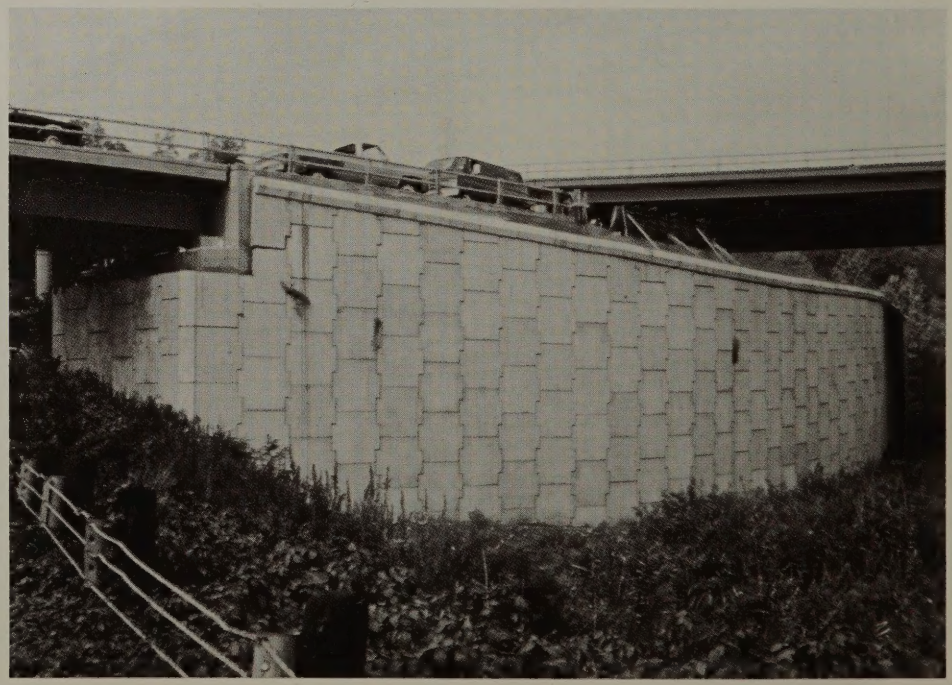

Figure 9. View of east wall looking north.

Figure 10. Barrier construction.

These and other problems were solved by the engineer-in-charge and the contractor. The project turned out remarkably well and all expectations are that this Reinforced Earth ramp will continue to perform satisfactorily.

The contract cost for all Reinforced Earth structures built on the Sprain Brook Parkway project including related excavation, all pre-manufactured components, granular backfill, and concrete leveling pads, was about $27/sq ft of wall face. Obviously, this is much less than cast-in-place reinforced concrete construction.

It has been asked whether Reinforced Earth would have been the best choice for the SM ramp if the large, actual settlements which were experienced could have been predicted. The author concludes that Reinforced Earth was indeed the best choice even though acceptance of this design by the project designers might have been difficult under such circumstances. In fact, the significant settlement differentials were not damaging and the Reinforced Earth section of the ramp is an impressive structure.

Summary and Conclusions

The SM Ramp connecting the Saw Mill River Parkway and the Cross Westchester Expressway follows a curved, horizontal alignment over varying foundation soils. The vertical alignment is on steep grades.

Reinforced Earth was specified as the material of choice for this project. Reduced drag on existing piers, accommodation of differential settlements, and lower construction costs were the reasons for this selection. Even though the actual settlements were greater than anticipated, the structure's appearance and performance are unaffected.

Overall, Sprain Brook Parkway project, with more than 118,000 sq ft of Reinforced Earth retaining walls and bridge abutments with wingwalls, is the New York State Department of Transportation's largest application of this construction technology.

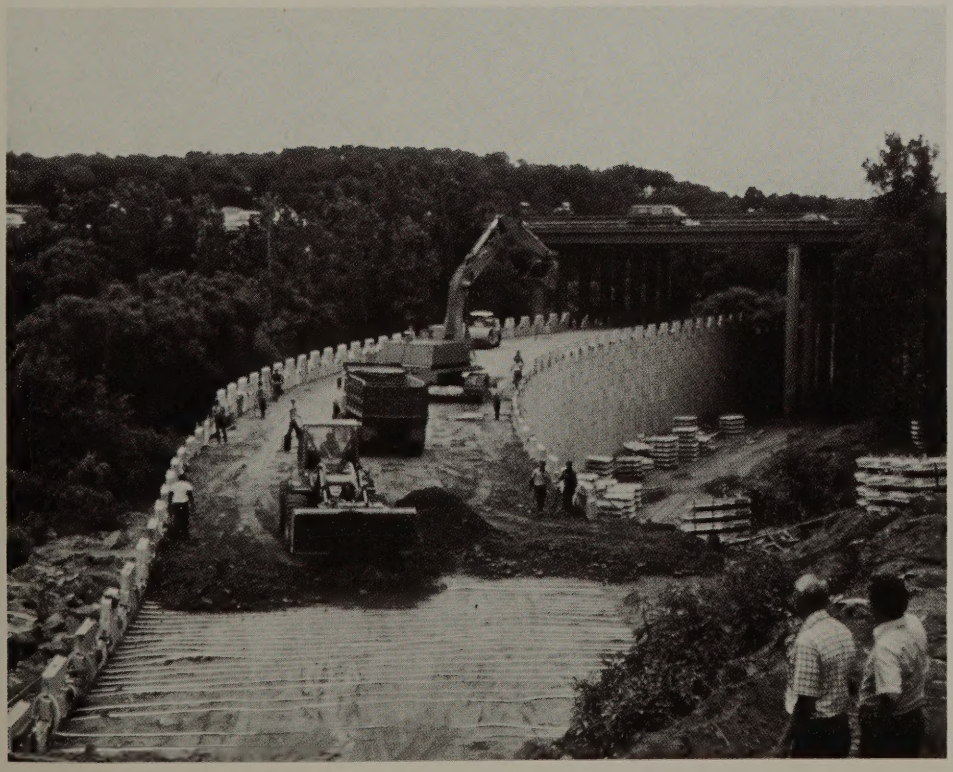

Figure 11. Ramp construction looking south.

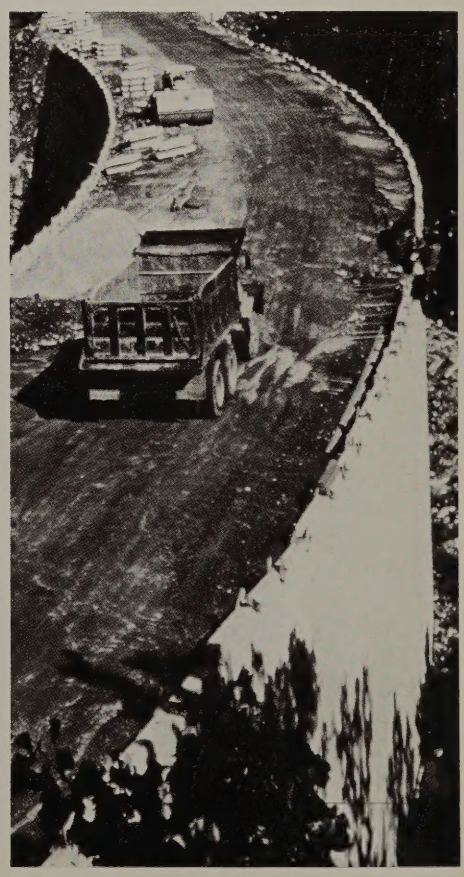

Figure 12. Ramp construction looking north to Saw Mill River Parkway.

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